

MEETING ATTENDANCE LIST

Licensee: Entergy

Plant: Vermont Yankee Nuclear Power Station

Subject: General Electric Steam Dryer Analysis Methodology

Date: July 21, 2004 Time: 8:00 a.m.

Location: NRC Headquarters, TWFN Room 8A1

| Name | Title | Organization |
|---------------------|--------------------------|------------------------|
| Rick Ennis | Senior Project Manager | NRC/NRR/DLPM |
| Gene Imbro | Chf; Mech & Civil Eng Br | NRR/DE |
| THOMAS M. CIZANUSAS | EPC TASK manager | VERMONT - ENTERGY |
| PEDRO B. PEREZ | SR. ENGINEER | VERMONT YANKEE |
| RAJU ANANTH | PROJECT ENGINEER | STRUCTURAL INTEGRITY |
| Jim DeVincentis | LICENSING MANAGER | ENTERGY VERMONT YANKEE |
| George Strambach | Regulatory Services | GENE |
| DAN PARDONE | ENGINEER | GENE |
| Alex Pinsker | ENGINEER | GENE |
| Cayetano Santos | Sr. Staff Engineer | NRC/ACRS |
| RALPH CARUSO | Sr Staff Engineer | NRC/ACRS |
| SHAH MALIK | SP. Materials Engineer | NRC/RES |
| MIKE SCHRAG | MANAGER | GENE |
| Richard Wu | Engineer | GENE |
| Henry Hwang | Engineer | GENE |
| JIM KLAPPENH | MGR, ENGR TECH | GENE |
| Leslie Wellsten | Engineer | GENE |
| Guy DeBoo | Sr. Staff Engineer | EXELON |
| Carl Hinds | Sr. Engineer | GE |
| RICK CUTSINGER | Civil Manager - BEA | TVA |

| Name | Title | Organization |
|--------------------|--------------------------|-----------------------------------|
| JOHN G. LAMB | PROJECT MANAGER | NRC/NRR/DLPM |
| Jenny Weil | Managing Editor | McGraw-Hill |
| Bill Ruland | Project Director | NRC/NRR/DLPM |
| Chris Games | Deputy DE | NRC/NRR |
| Dana Skay | Senior Project Manager | NRC/NRR/DLPM |
| Jorge Hernandez | Reactor Engineer | REIDRP |
| Douglas Rosinski | Attorney | Shaw Pittman |
| Allen Howe | Section Chief | NRC/NRR |
| BARRY ELLIOT | NRC/NRR/DE/EMCB | MATLS. ENG |
| Bo Pham | NRR/DLPM PM | NRR/DLPM |
| CORNELIUS HOLDEN | PD-2 | NRR/DLPM |
| David Terao | Section Chief | NRC/NRR/EMEB |
| Douglas Kalinovsky | Materials Engineer | NRC/RES |
| Thomas Scarborough | Senior Mech. Engineer | NRC/NRR/EMEB |
| DON HELTON | Reactor Systems Engineer | RES/DSARE/SMSAB |
| GEORGE C NELSON | CONSULTANT-EPU | BECHTEL/TVA |
| Larry Yemma | Lead Engineer | Progress Energy |
| Ed Hartwig | Project Manager | TVA/James Ferry |
| Glen Ohlenacher | Project Manager | Detroit Edison/BWROG |
| John McCann | Dir. - Licensing EPNR | ENERGY |
| Louis Quintana | Mgr., GENE Licensing | GENE |
| HAR MEHTA | Engineering Fellow | GENE |
| John Dreyfuss | Dir. Eng'g | ENERGY-VY |
| CRAIG J NICHOLS | EPU PROJECT MANAGER | ENERGY-VY |
| KAMAL MANOLY | NRC/NRR/DE/EMEB | Chief, Civil & Eng. Mech. Section |
| JOHN WU | NRC/NRR/DE/EMEB | MECHANICAL ENGINEER |
| Tom Mulcahy | ANL - NRC subcontract | Senior Mech. Engr. |

MEETING ATTENDANCE LIST

Licensee: Entergy

Plant: Vermont Yankee Nuclear Power Station

Subject: Steam Dryer Analysis Associated with Extended Power Uprate Request

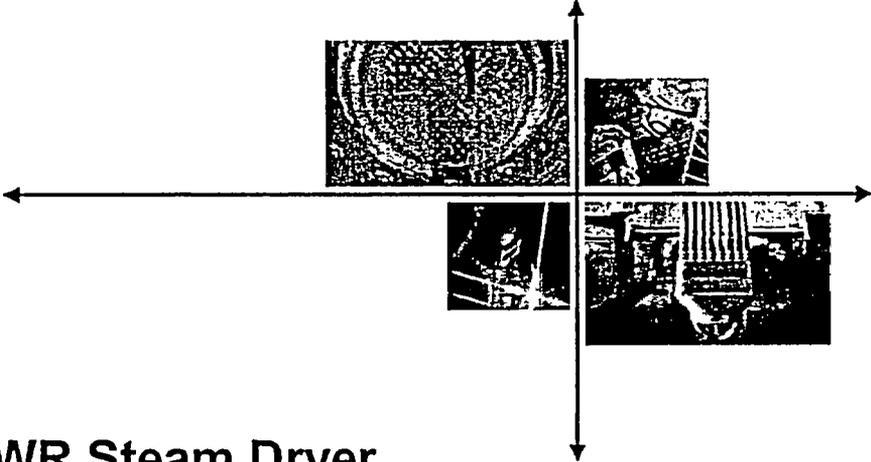
Date: July 22, 2004

Time: 8:00 a.m.

Location: NRC Headquarters, OWFN Room 1G16

| Name | Title | Organization |
|------------------|-------------------------|-------------------------|
| Rick Ennis | Senior Project Manager | NRC/NRR/DLPM |
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| Richard Wu | Engineer | GENE |
| HAR MEHTA | Engineering Fellow | GENE |
| MIKE SCHRAG | MANAGER | GENE |
| STIM KLAPPROTH | ENR MGR ENGR | GENE |
| Larry Yemma | Lead Engineer | Progress Energy |
| Glen Ohlemacher | Project Manager | DTE Energy /BWR06 |
| Scott Gardwin | Supervisor | Entergy Vermont Yankee |
| TOM CIRAUSKAS | ENGINEER | ENTERGY Vermont Yankee |
| PEDRO B. PEREZ | ENGINEER | ENTERGY VY |
| Douglas Rosinski | Attorney | Shaw P. Hman |
| RAJU ANANTH | CONSULTING ENGINEER | Structural Integrity/VY |
| LARRY ROSSBACH | Project Manager | NRC/NRR/DLPM |
| Math Young | Summer Hire | NRC/NRR/DE/EMER |
| GEORGE NELSON | BFN EPU PROJECT | BECHTEL/TVA |
| RICK CUTSINGER | CIVIL RESTART MGR - BFN | TVA |
| Ed Hartwig | Project Manager | TVA |
| Guy DeBoo | Sc. Staff Engineer | EXELON |
| Alex Pinsker | Engineer | GENE |

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| Henry Hwang | Engineer | GENE |
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| George Strambach | GENE-Regulatory Services Mgr | |
| John McCann | Director - Licensing | ENERGY |
| John Dreyfuss | Director - Eng'g | ENERGY - VY |
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| Gene Imbro | Chf. Mech & Civil Eng | NRC |
| KAMAL MANOLY | Chf. Civil & Eng Mech. Section | NRC |
| Tom Mulcahy | Argonne National Senior MGR | ANL |
| Vik Shah | Mech. Engineer | ANL |
| John Wu | Mech. Engineers | NRC |



**BWR Steam Dryer
Structural Analysis Methodology**

July 21, 2004

Dryer Structural Analysis Methodology Meeting 7/21/2004 Slide 1 

Agenda

- Meeting Goals
- Meeting Structure
- EPU Operating Experience
- Fluctuating Load Definition
- Structural Analysis Techniques
- Finite Element Model
- Fatigue Structural Analysis
- Load Combinations
- Transient and Accident Load Definitions
- Primary Stress Structural Analysis

Dryer Structural Analysis Methodology Meeting 7/21/2004 Slide 2 

ATTACHMENT 3

Meeting Goals

- Update NRC technical staff on BWR steam dryer structural analysis methodology
 - Load definition
 - Structural analysis
- Provide generic basis and background information supporting EPU dryer analyses
- Provide information supporting VY dryer analysis review

Significant improvements in methodology have been made over the last year



Meeting Structure

- Informal question/answer format
 - Similar to technical audit
 - Not a structured presentation
- Review
 - Detailed analysis results
 - Design record files
 - Spreadsheets, etc
- Review of generic methodology
 - Vermont Yankee EPU analysis used as example
- Copies of materials requested by the staff will be formally provided after the review



GENE Technical Discussion Leaders

- Fluctuating Load Definition Dan Pappone
- Structural Analysis Techniques Richard Wu
- Finite Element Model Alex Pinsker
- Fatigue Structural Analysis Henry Hwang
- Load Combinations Henry Hwang
- Transient and Accident Load Definitions Dan Pappone
- Primary Stress Structural Analysis Henry Hwang

Dryer Structural Analysis Methodology Meeting 7/21/2004

Slide 5

Imagination at work



Steam Dryer Design Basis

- Original Design Requirements
 - Not ASME-coded component
 - Fatigue from flow-induced vibration not explicitly considered
 - Maintain structural integrity for outside steamline break accident
 - No loose parts
 - Deformation acceptable
- Current Dryer Analyses
 - Finite Element Model of dryer
 - Fluctuating pressure loads defined
 - Fatigue from flow-induced vibration analyzed
 - Normal, upset, faulted conditions analyzed
 - ASME code criteria used as guidance for modifications

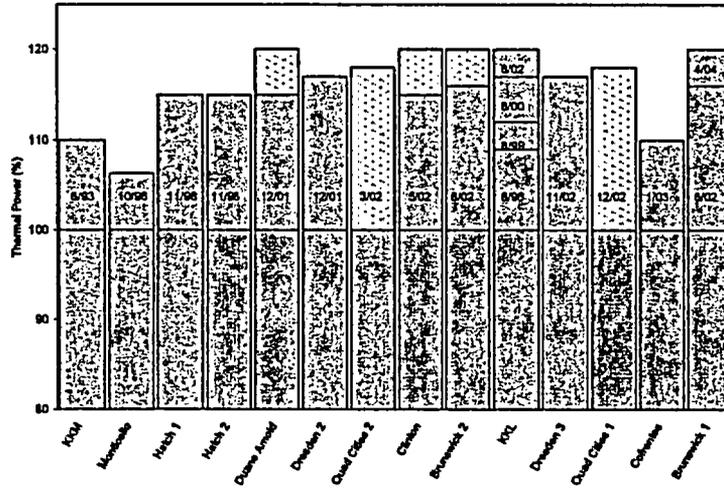
Dryer Structural Analysis Methodology Meeting 7/21/2004

Slide 6

Imagination at work

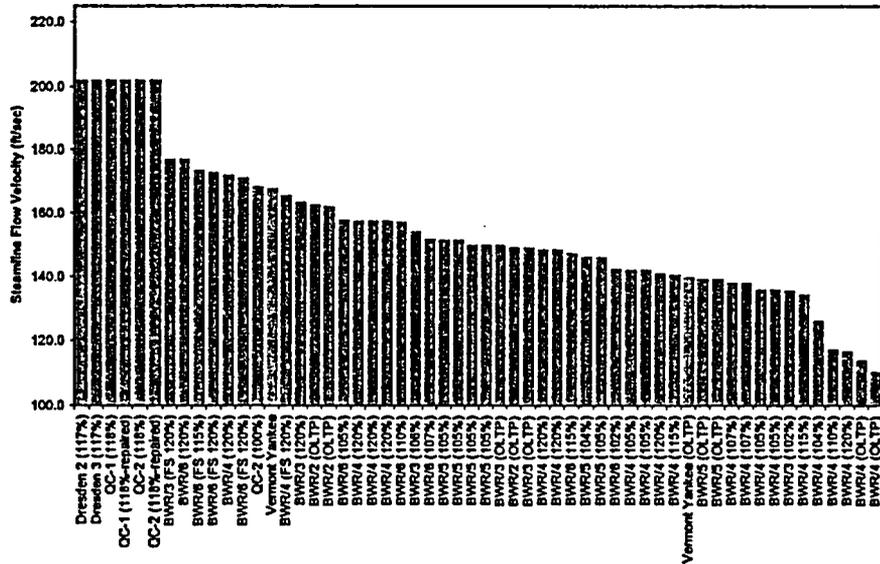


EPU Operating Experience



Nearly 50 Reactor Operating Years of EPU Experience

Steamline Flow Velocities



BWR/3 Dryer Failure History (QC2)

| | | | | |
|------------|--|---|---|---|
| June 2002 | Dislodged 1/4" lower cover plate at QC2 | High cycle fatigue due to high frequency fluctuating pressure (120-230 Hz), thin cover plate, small welds, potential resonance | Replaced cover plate with 3/4" plate Used more robust attachment welds. | Developed dryer component structural analysis |
| May 2003 | Cracks in outer hood, broken braces and struts in the outer hood | High cycle fatigue due to low frequency fluctuating pressure loading (<50 Hz) Operation with damaged cover plate contributing factor | Removed diagonal braces from outer hoods Replaced outer hood plates with 1" plate Added external gussets | Modified dryer structural analysis to account for fluctuating pressure load definition over full frequency range, for all dryer types |
| March 2004 | Cracks in plate at gusset tips, broken tie bar welds | Local stress concentrations not modeled in sufficient detail | Full height 1" vertical hood plate Full height external gussets Full penetration shop welds on external gussets | Solid submodels for high stress locations used to supplement 3D shell Finite Element model Analysis includes gusset tip design and weld design |

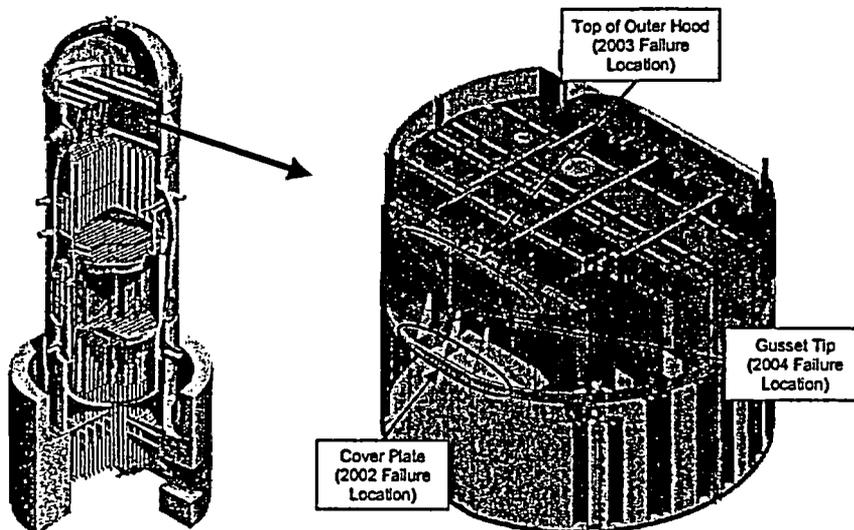
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Slide 11

Imagination at work



Hood Failure Locations



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Slide 12

Imagination at work



Imagination at work



Review Topics

- Load Definition
- Structural Analysis
- Plant Application



Conclusions

- Significant progress in structural analysis methodology
- Overall methodology is conservative
- Dryer modifications assure structural integrity at EPU conditions
 - Increased design margin at critical locations



Closed Session



Fluctuating Load Definition

- Generic load definition
 - Assumptions
 - In-plant test data
 - Scale model test data
 - Reference load definition
- Plant-specific application
 - Load scaling
- Load definition confirmation



Structural Analysis Techniques

- Equivalent static method
 - Frequency analysis using reference load
 - Load scaling
 - Dynamic amplification, stress concentration factors
- Response spectrum method
 - Pressure load to response spectrum transform
- Acceptance Criteria

Dryer Structural Analysis Methodology Meeting 7/21/2004

Slide 17

Imagination at work



Finite Element Model

- Model Assumptions
- Dryer components modeled
- Shell model
- Solid submodels

Dryer Structural Analysis Methodology Meeting 7/21/2004

Slide 18

Imagination at work



Fatigue Structural Analysis

- Analyze current power, EPU power conditions
- Benchmark current power results against acceptance criteria
- Evaluate EPU results against acceptance criteria

Dyer Structural Analysis Methodology Meeting 7/21/2004

Slide 19

Imagination at work



Load Combinations

- Operating conditions
 - Normal
 - Upset
 - Faulted
- Loads considered
 - Deadweight
 - Static differential pressure
 - Seismic

Dyer Structural Analysis Methodology Meeting 7/21/2004

Slide 20

Imagination at work



Transient and Accident Load Definitions

- Differential pressure loads
 - Forward flow transients (e.g., SORV)
 - Reverse flow transients (e.g., TSV)
 - Steamline break accident
- Seismic loads
 - OBE
 - SSE



Primary Stress Structural Analysis

- Analyze individual load components for each operating condition
- Combine stress results for individual components
- Assess overall stress results against acceptance criteria





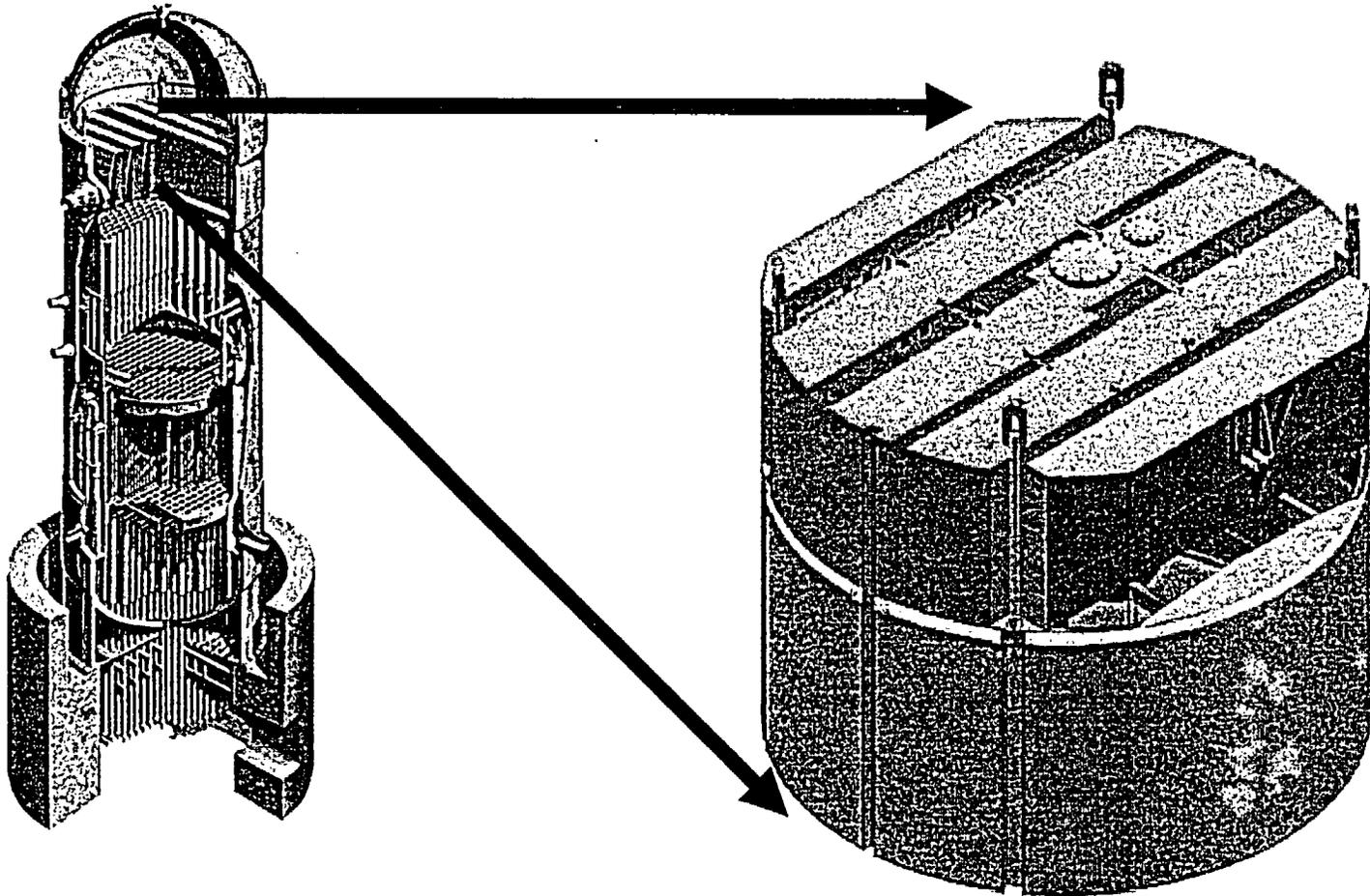
Entergy VY Power Uprate Project

Steam Dryer RAI Review

July 22, 2004

ATTACHMENT 4

Main Steam Dryer





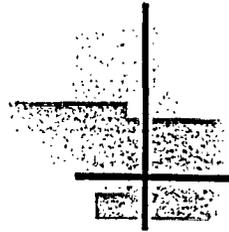
What we know

- Significant improvement in methodology
- Dryer Finite Element Model adequately reflects dryer performance under defined load
- VY Modified Dryer relative stresses are less than other dryer types under the same load
- Dryer Loads are adequately defined
- VY Steam Line velocity at EPU is less than QC/Dresden original steam velocity
- Reasonable Assurance that Dryer will perform per current design requirements at Extended Power Uprate Conditions at Vermont Yankee



Future Activities

- Obtain and evaluate VY Plant Specific data
- Comprehensive, deliberate, well monitored power ascension



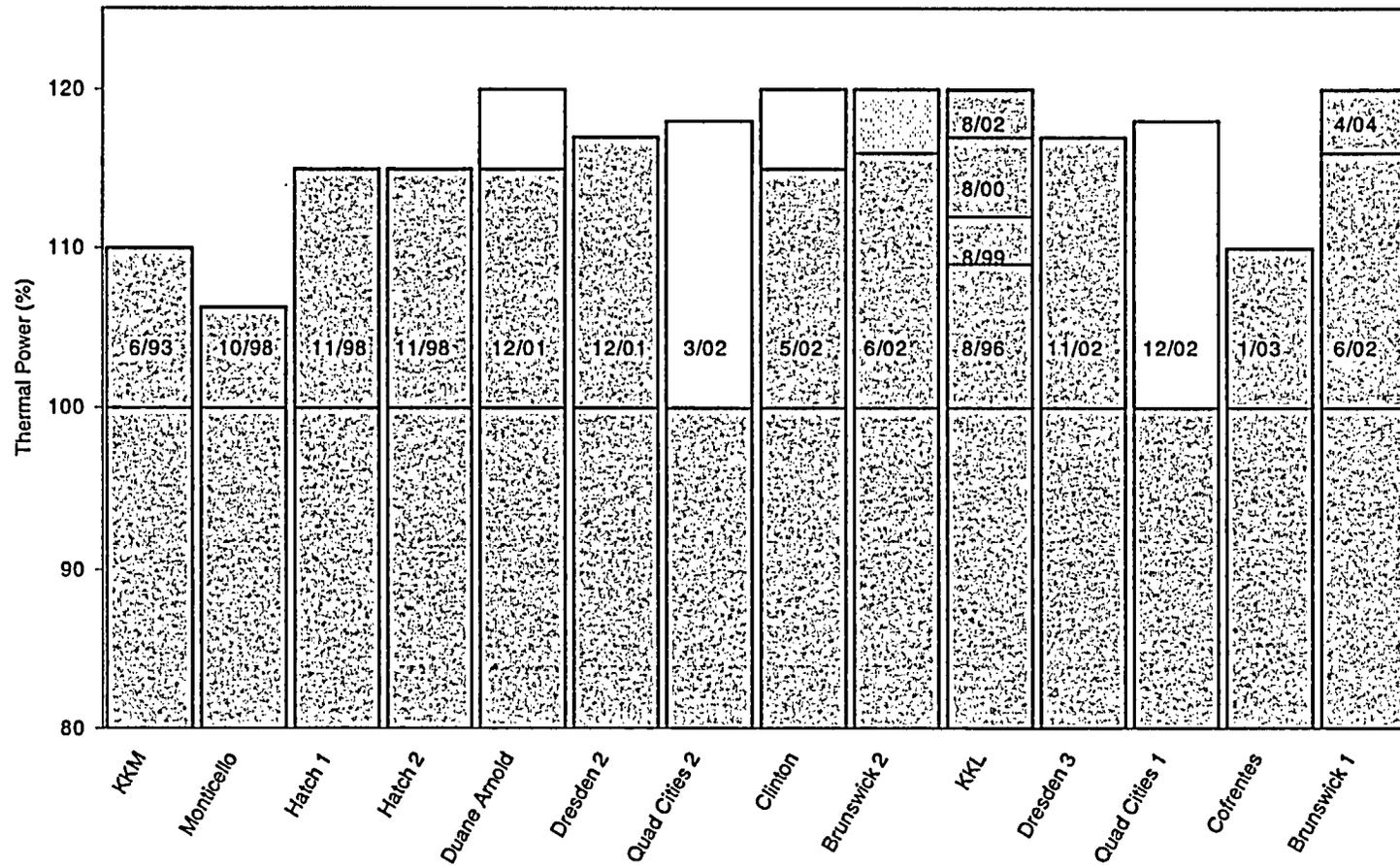
Quad Cities Experience

- Methodologies developed after QC2 failures accurately predict high stress locations
- Confirmed by actual high stress failure locations

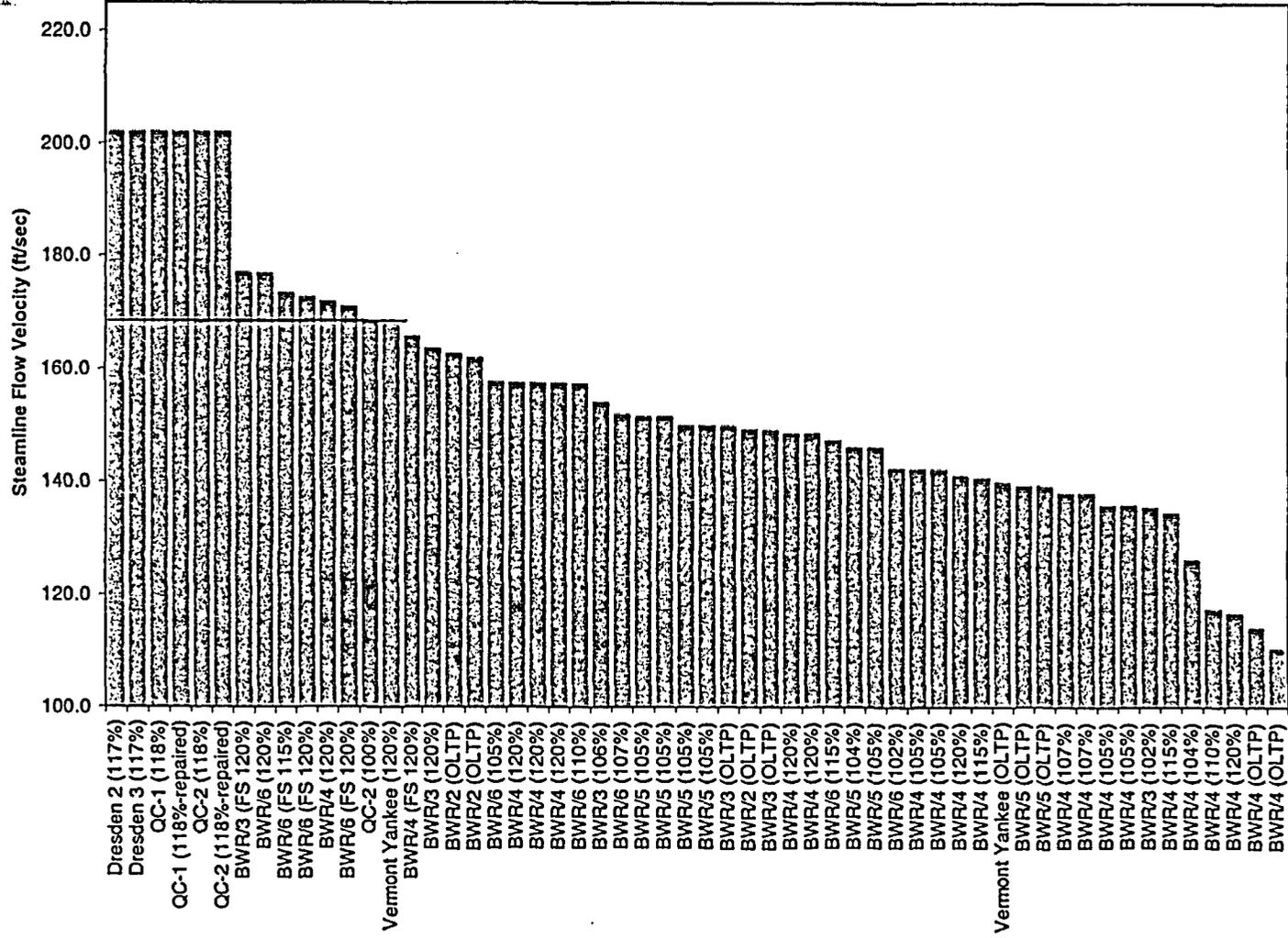


Industry Steam Dryer Experience

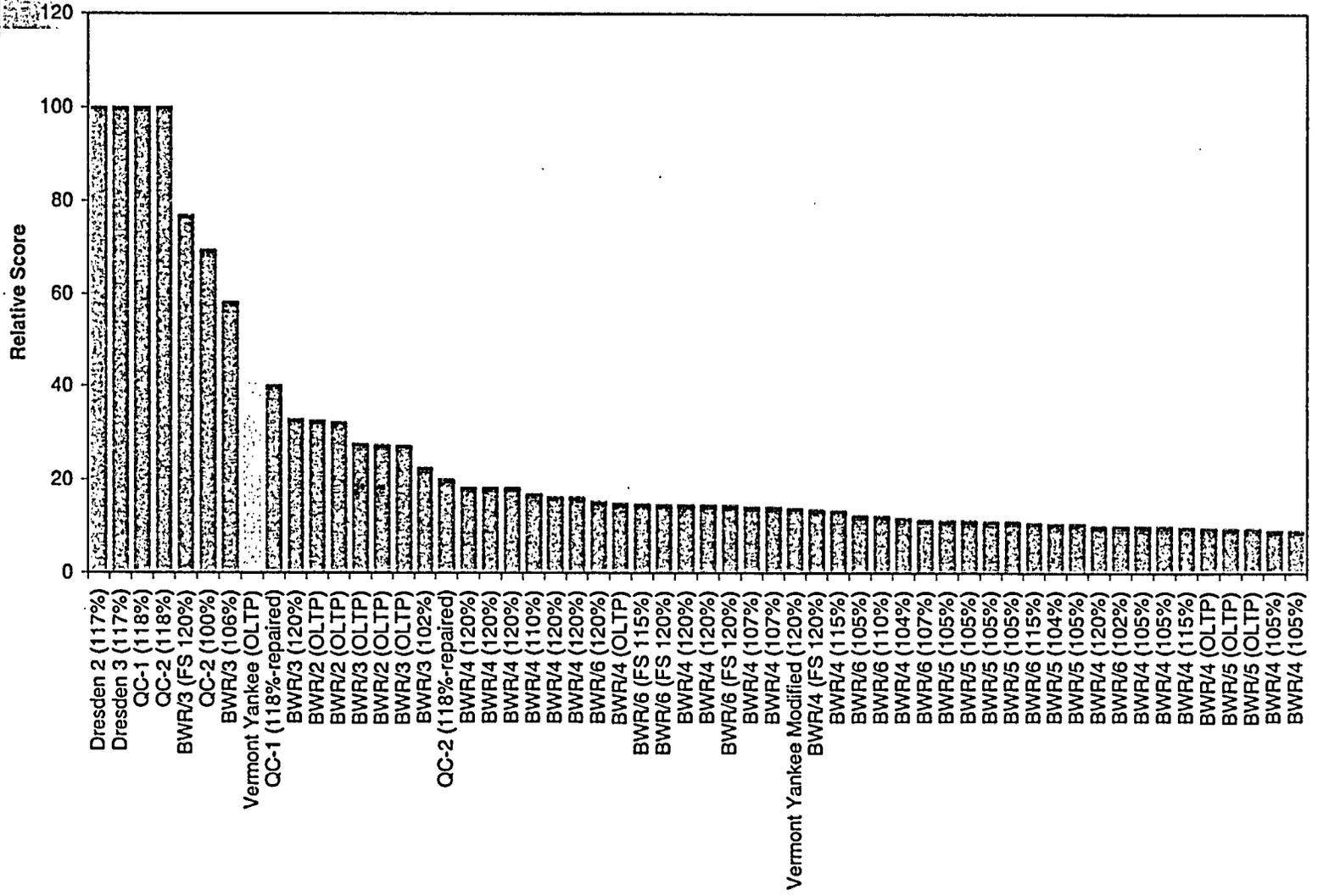
Nearly 50 Reactor Operating Years of EPU Experience



Main Steam Line Flow Velocities



Overall Dryer Screening



VY Steam Dryer Analysis

- GE developed Finite Element Model of VY Dryer
- Loads defined based on similar plant instrumented dryer data
- Results: identified increased stress areas at uprate conditions
- Developed robust modification – industry experience incorporated
- Re-ran the Model incorporating the modification and validated stresses were below Code limits at uprate conditions
- Significantly increased structural margin



VY Steam Dryer Inspection

- Internal & external visual inspection of steam dryer accessible areas
 - No outer bank or lower cover plate cracking found



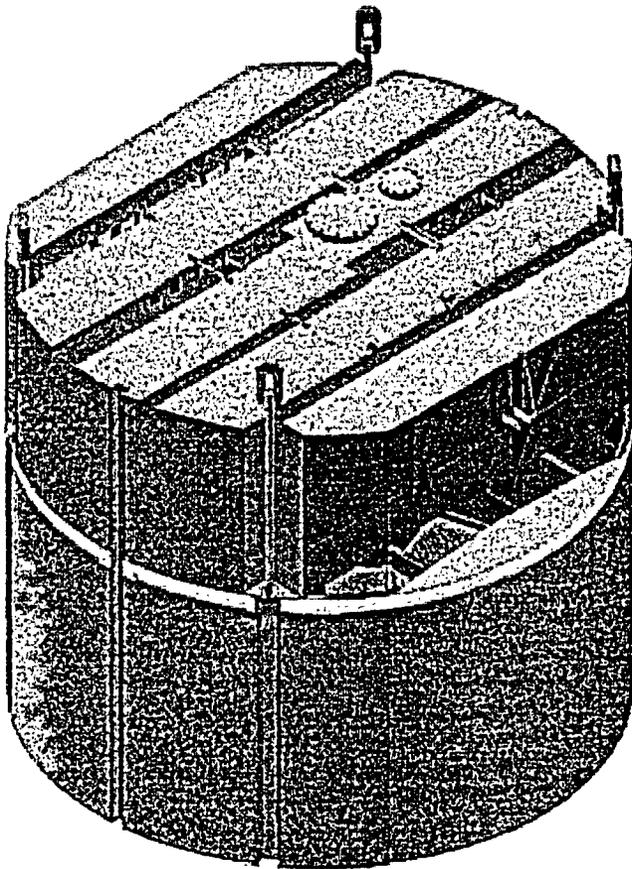
VY Steam Dryer Inspection

- Some visual indications were found: consistent with BWR industry experience
 - Two 3" cracks in dryer steam dam were repaired & strengthened
 - Caused by fabrication residual stresses
 - Several intergranular stress corrosion cracks (IGSCC) were found (dryer end bank and drain channel)
 - Caused by sensitization and weld residual stresses from original welding
 - Not structurally significant

Steam Dryer – Strengthening Design

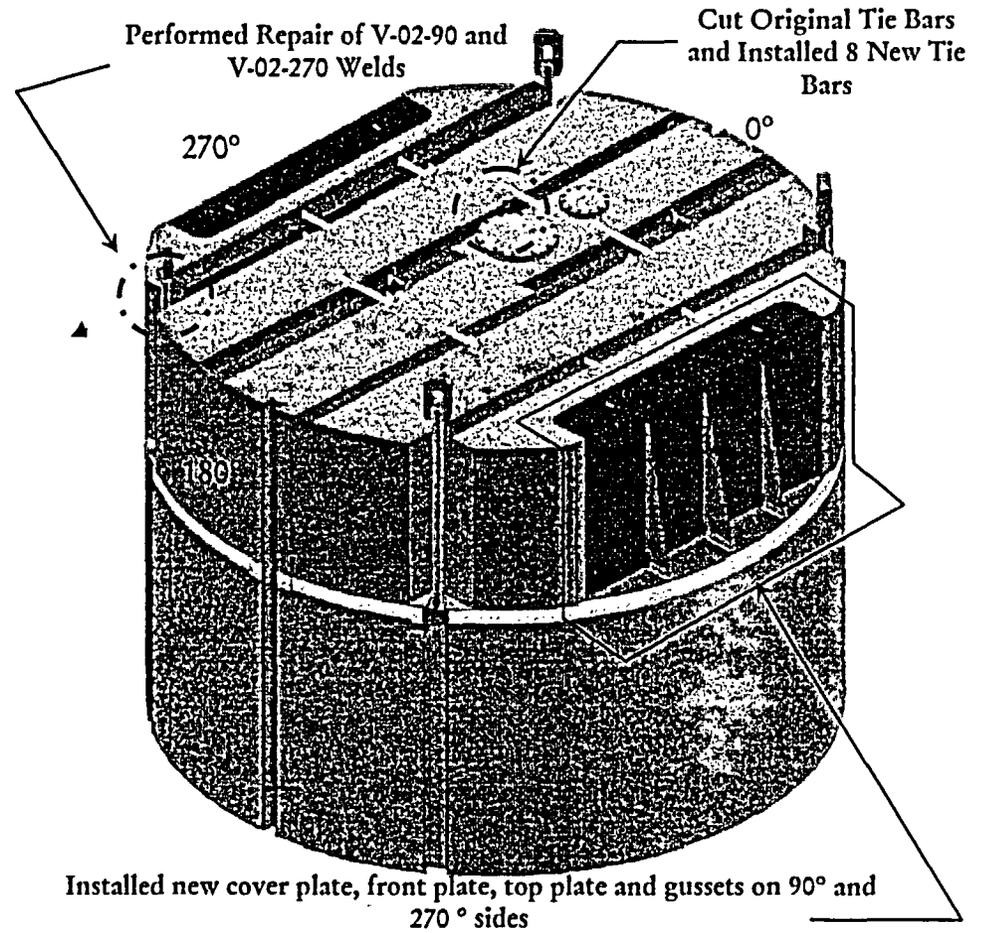
- Modifications
 - Lower cover plate – Increase from 1/4" to 5/8" Upper vertical and horizontal cover plates in outer hood – Increase from 1/2" to 1"
 - Remove internal diagonal shipping braces
 - Eliminate stress concentrators which were the crack initiators for the Quad Cities Failures
 - Replace dryer bank tie bars and improve weld attachment
 - Add six, full-length external gussets to hood plates
 - Full penetration versus fillet welds
 - Gusset shoe provides enhanced weld strength
 - Employed low carbon stainless steel – IGSCC resistant

VY Dryer - Before & After Strengthening



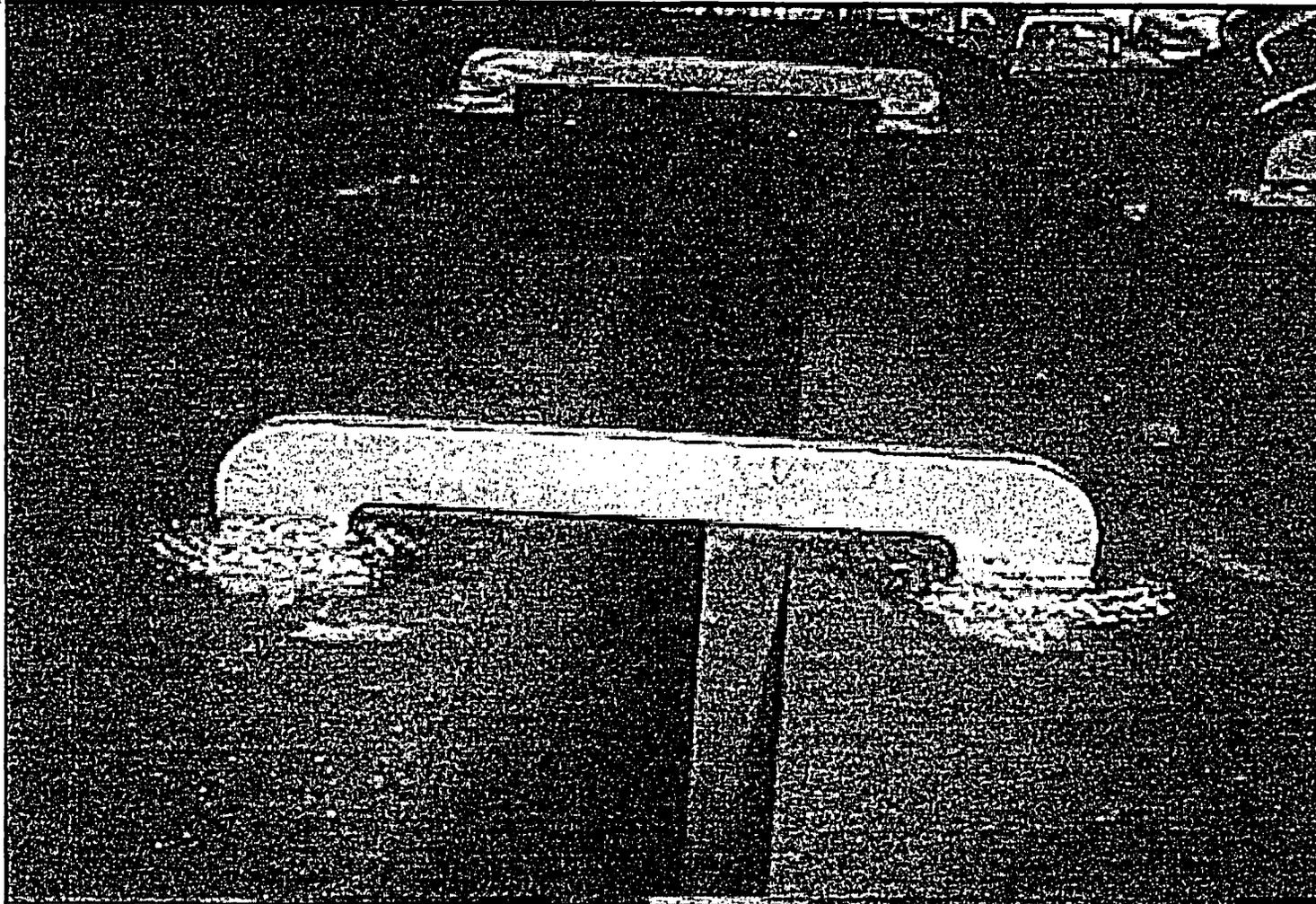
Before

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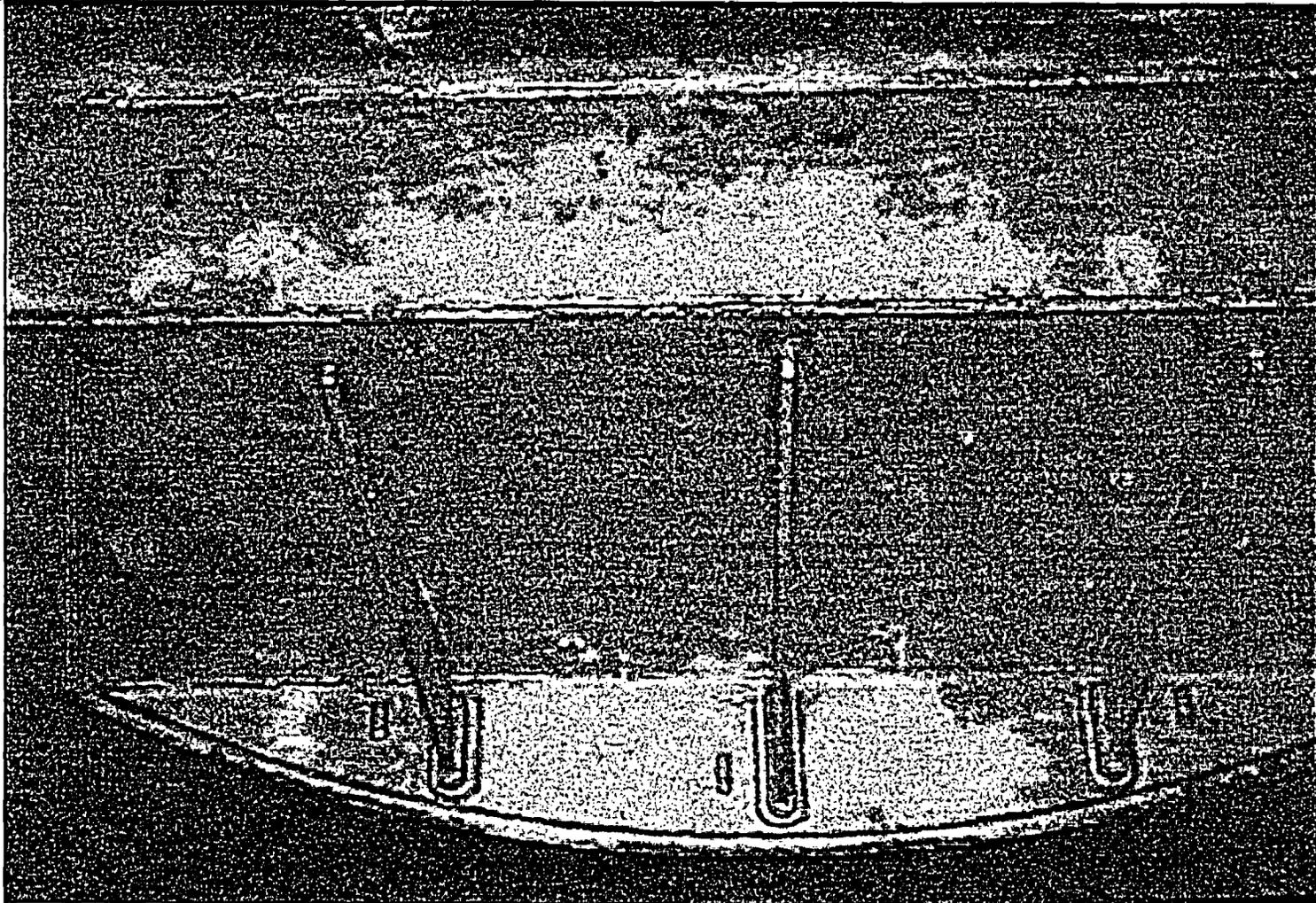


After

VY Steam Dryer Strengthening – Tie Bars



VY Steam Dryer Strengthening – Hood



VY Steam Dryer Monitoring

- Measurements consistent with SIL 644
 - Moisture carryover levels
 - System parameters (flow and level)
- Inspection in planned refuel outage (~8 months of <115% uprate operation)



VY Acoustic Circuit Model

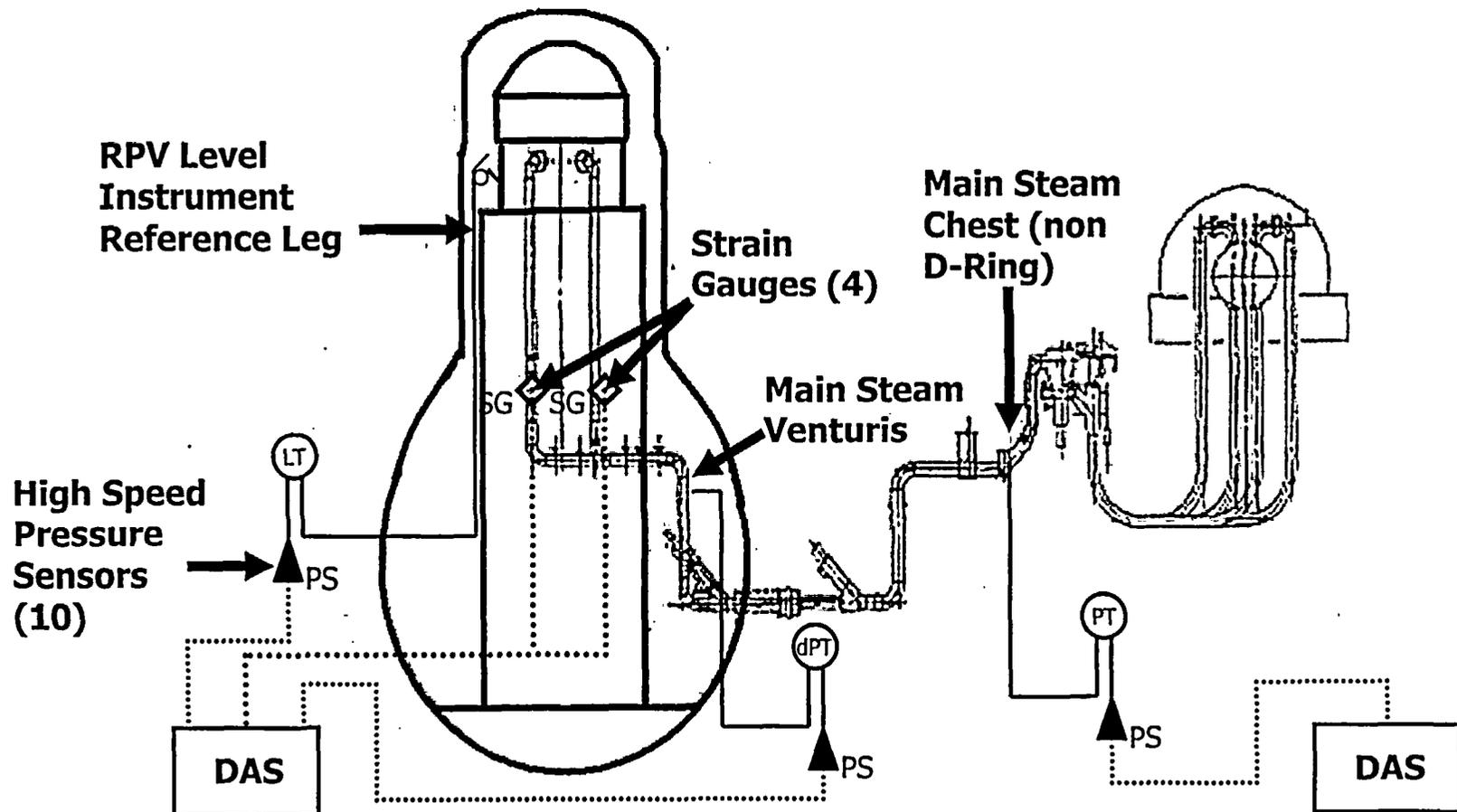
- Collect VY Main Steam Data
- Develop Acoustic Circuit Model
- Reconcile Test Results with GE Analysis

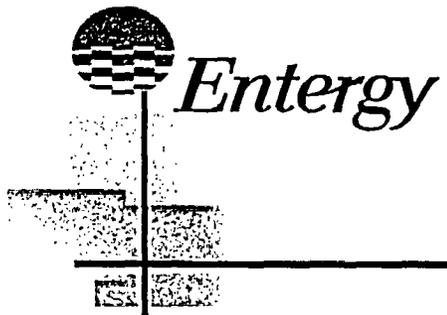


VY Main Steam System Data Collection

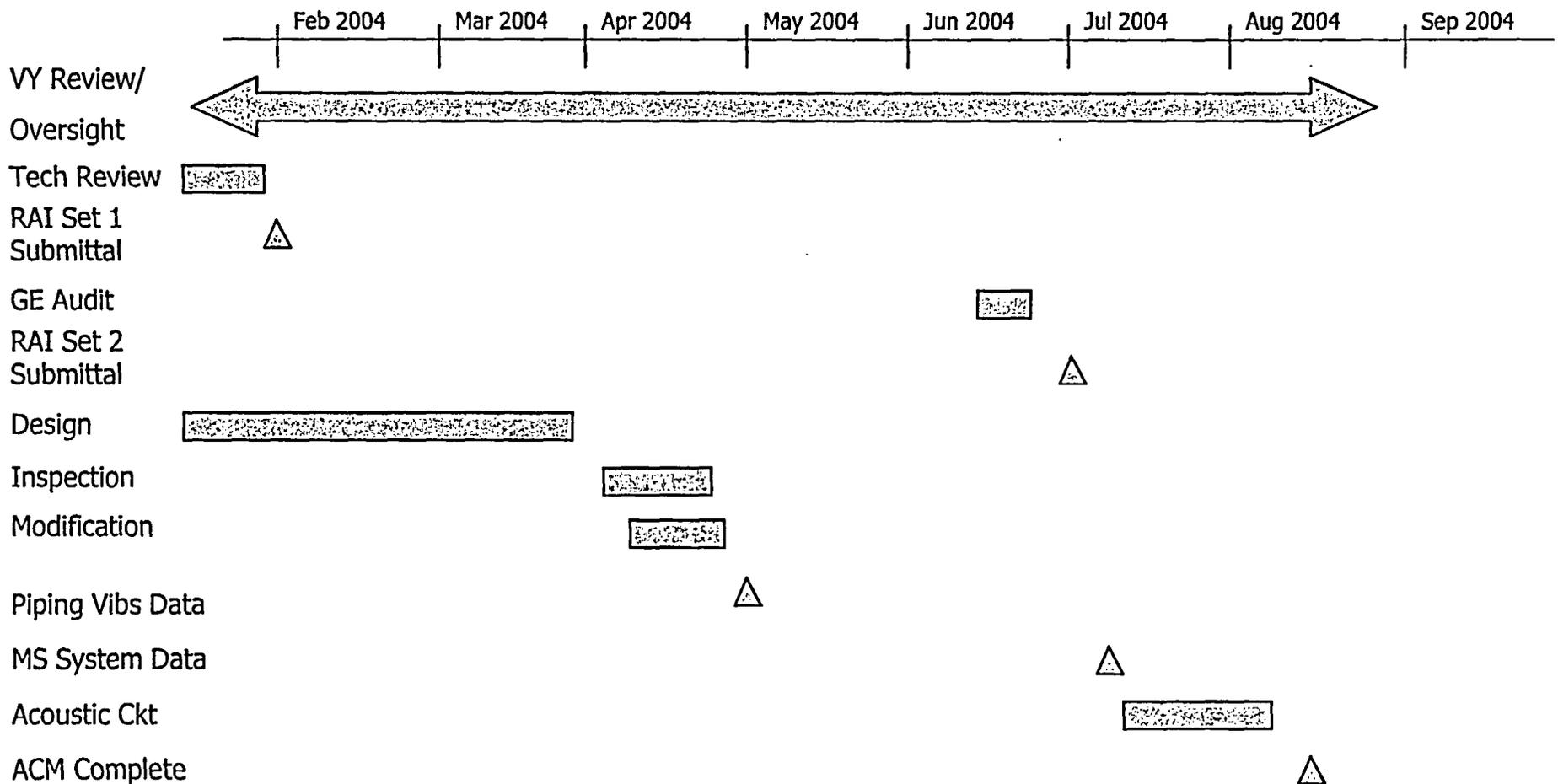
- Measurement locations more extensive than other stations
 - Pressure data taken with high speed recorder at:
 - MSL venturis (one on each steamline)
 - Vessel instrument reference legs (2)
 - Main steam header
 - Strain Gauges located on each steam line close to vessel
- Data taken at 80%, 85%, 90%, 92%, 95%, 97% and 100% power

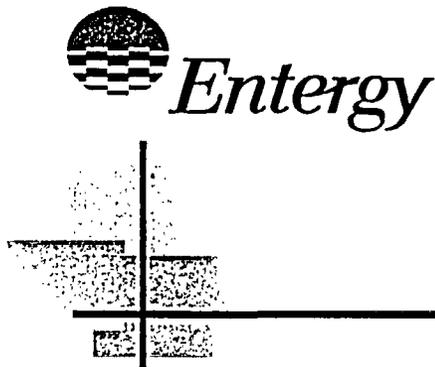
VY Steam System Data Collection Map





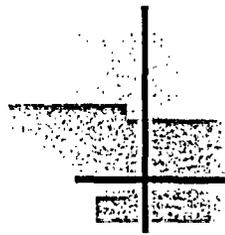
VY Steam Dryer Timeline





VY Uprate Testing and Inspection Plan

- Two Step Uprate
- Gradual Power Ascension Test Plan with predefined hold points
 - Pre-uprate testing provides baseline data
- Measurement program
 - Main Steam and Feedwater FIV Accelerometers
 - Steam System Pressure Transmitters
 - Main Steam Line Strain Gauges
 - Installed Plant Equipment
- Inspection in planned refuel outage (8 months of <115% uprate operation)
 - Detailed inspection consistent with SIL 644



Q&A
